NILS Niedersächsische Lernwerkstatt für solare Energiesysteme
am Institut für Solarenergieforschung ISFH Hameln Geschäftsführer Prof. Dr. R. Brendel
An- Institut der Leibniz Universität Hannover
Am Ohrberg 1 – D-31860 Emmerthal Tel.: 05151 999 100 Fax: 05151 999 400
email: nils@isfh.de web: www.nils-isfh.de www.isfh.de mobil: 0175 766 06 07 (W.R. Schanz)

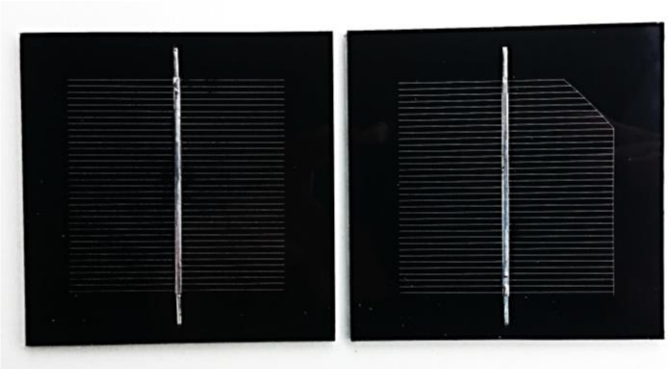
Photovoltaik-System SUSE

Solarthermiesystem Wärme von der Sonne

innovative Solarsysteme für Schule und Ausbildung

BNE Bildung für Nachhaltige Entwicklung

SUSEmod218- a powerful, highly efficient, robust solar module



The solar module SUSEmod218

Inside, the epoxid resin coated monocrystalline Si solar cell is visible, on the left-hand side a square element, on the right-hand side a corner piece with a slanted corner, characteristic for monocrystalline solar cells.

Module dimensions: 75 x 75 mm
Cell dimensions: 52 x 52 mm

The newly designed **Sundidactics solar module SUSEmod218** is the advancement of the module SUSEmod215 used so far. The solar module **SUSEmod218** contains one monocrystalline high-performance solar cell with the dimensions 52mm x 52mm x 0,18mm. The solar cell is embedded break-proof in a plastic plate of the dimensions 75 x 75 mm. The surface on top of the solar cell is grouted/laminated with highly transparent plastic, material: epoxy/resin. On the back side there are two soldering contacts for soldering on the positive and negative conductors (hookup wire). The solar module can be fixed on smooth surfaces by double-faced adhesive tape or glue on the back side.

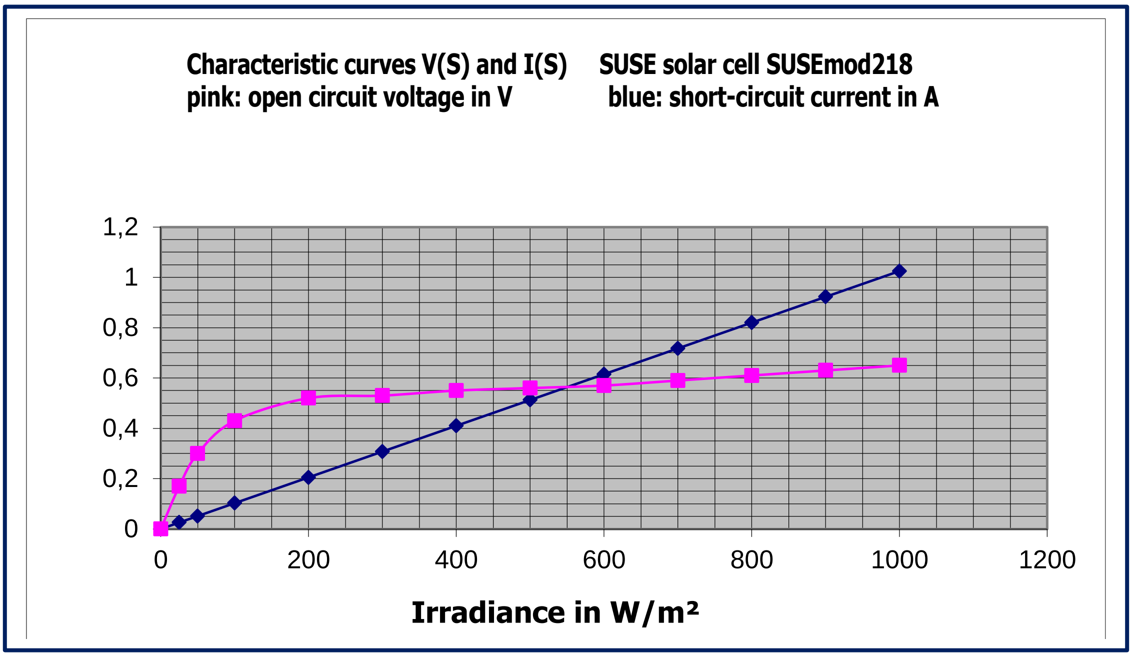
Module: Plastic support, square 75 x 75 x 2,6 mm with highly transparent surface, mechanically very robust
Solar cell: Monocrystalline solar cell 52 x 52 mm, square, top surface blue-black through SiN anti-reflection layer, surface dull because of acid texturing.

Technical Data with an irradiance of 1000 W/m², T = 25°C, AM = 1,5 Tolerance 2 %

Physical value	Symbol	Numeric value	Physical unit	Annotations
Dimensions	s	52 x 52 x 0,18	mm	Square cell, 1/9 of a 6 inch solar cell
Area	A	27,04	cm²	1/9 of a 6 inch solar cell
Open circuit voltage	V_{OC}	0,656	V	Typical for silicon
Short-circuit current	I_{SC}	1,025	A	Proportional to the light intensity S
Voltage at MPP	V_{MPP}	0,507	V	Voltage at MPP (Maximum Power Point)
Short-circuit current at MPP	I_{MPP}	0,942	A	Short-circuit current at MPP
Electric power	P	0,477	W	With S = 1000 W/m²,AM 1,5, 25°C
Degree of efficiency	η	19,1	%	Quality characteristic
Filling factor	FF	71	%	FF is a quality characteristic
Current density	j	38,15	mA/cm²	j is a quality characteristic
Thermal behaviour of open circuit voltage U_{oc}	ΔV_{oc}	- 0,36	% /K	The voltage decreases with heating by 0.36% per 1K
Thermal behaviour of short-circuit current I_{sc}	ΔI_{sc}	+ 0,06	% /K	The short-circuit current increases by 0.06 % per 1K
Serial resistor	R_{ser}	0,097	Ω	Serial resistance of the solar cell Resistance of the Si and the conducters
Shunt resistor	R_{shunt}	64,82	Ω	Parallel resistance of the solar cell through internal short circuits inside the Si

The characteristic curves of the solar cell in the module SUSEmod218

1. Dependence of open circuit voltage V_{oc} and short-circuit current I_{sc} on the light intensity (Irradiance S in W/m²)

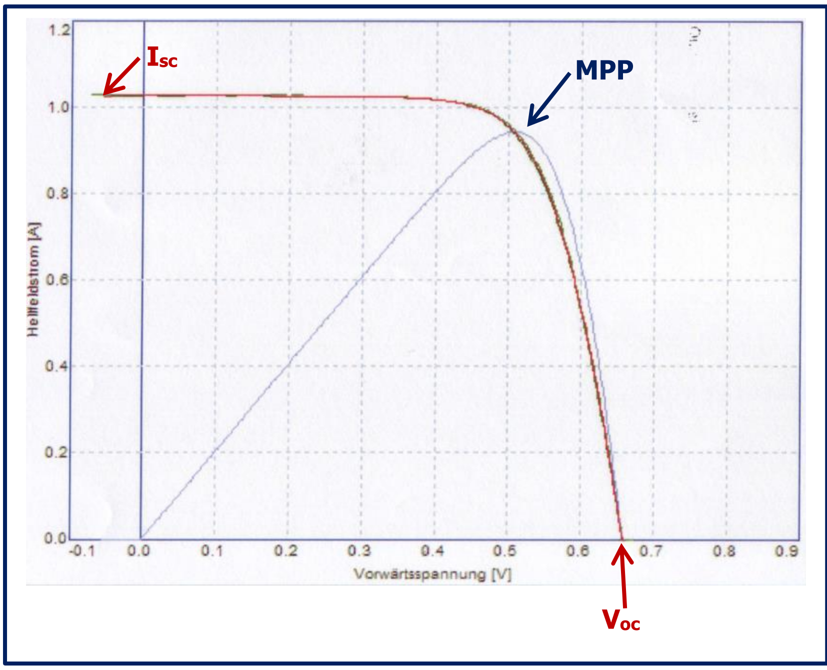


The **open circuit voltage V_{oc}** (exponential function!) is 0 in total darkness, increases strongly with small irradiances and then only slowly up to the maximum value of 0.64 V with 1000 W/m² (bright sunshine with blue sky, solar cell directed towards the sun).

The **short-circuit current I_{sc}** is a line through the origin and increaeses in a linear fashion from 0 in total darkness to 0.9 A with 1000 W/m².

2. Characteristic curves I(V) and P(V) of SUSEmod218 (S = 1000 W/m², T = 25°C, AM 1,5)

Measured in the characteristic laboratory oft the ISFH

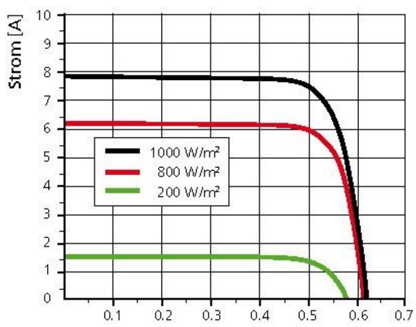


The **I-V characteristic curve** shows the dependence of the current on the voltage with a load of the solar cell in form a load resistor, with an irradiance of 1000 W/m² and a temperature of 25°C.
The intersection with the x-axis (V-axis) is the open circuit V_{oc}, the intersection with the y-axis (I-axis) is the short-circuit current I_{sc}.

The P-V characteristic curve is the power curve, it's maximum is the
Maximum Power Point MPP
of the solar cell.
That is the point of maximum power output of the solar cell.
With the photovoltaic measurement module SUSE 5.15 this curve can be recorded in an experiment.

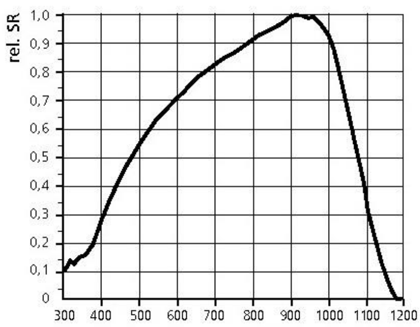
3. Additional data (for the whole solar cell 156 x 156 mm), for the solar cell 52x 52mm in the module SUSEmod218 the current in 3.1 and 3.3 has to be divided by 9!)

3.1 Intensity dependence



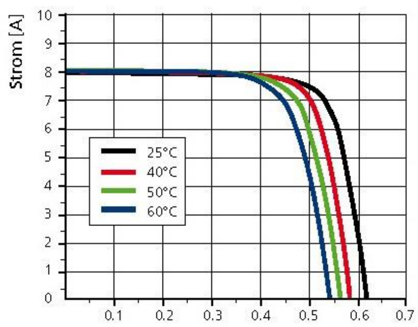
Voltage in V

3.2 Spectral sensitivity



Wavelength in nm

3.3 Temperature dependence



Voltage in V

The **graph on the left hand side 3.1** shows the **intensity dependence** of the **I(V) characteristic curves** dependent on the irradiance S of the irradiated light. (1000 W/m² is equivalent to bright sunshine in the sumer with a blue, cloudless sky, 0 W/m² is total darkness).

The **middle graph 3.2** shows the **spectral sensitivity** dependent on the wavelength of the light, the maximum sensitivity is reached at about 950 nm in near infrared. The cause is the band gap of silicon at about 1.1 eV, that results in light quantums in the range of 950 nm having exactly the right quantum energy and being perfectly suitable for the inner photoelectric effect. For light of shorter wavelengths the quantum energy is too high, the portion of the quantum energy not usable is emitted via kinetic energy of the freed up electrons as thermal energy into the lattice, which results in losses.
From this it follows that for experiments with Si solar cells filament bulbs or halogen spot lights are especially suitable, because they have a high percentage of IR light. White LED light is less suitable, because it contains barely any red or IR light.

The **graph on the right hand side 3.3** shows the **I(V) characteristic curve** in **dependence on the temperature**, it is recognizable that the open circuit voltage decreases, when the temperature increases, the short-circuit current only increases minimally with heating (j is the current density = short-circuit current in mA per cm² cell area). This also means, that the electric power P of the solar cell decreases with heating.

Open circuit voltage V_{oc} of a solar cell: $$V_{oc} = \frac{kT}{e} * \ln\left(1 + \frac{I_{sc}}{I_s}\right)$$

Short-circuit current of a solar cell: $I_{sc} = c * S$ c = const.

c is dependent on the area and the quality of the solar cell and can be determined experimentally.

V_{oc}= Open circuit voltage in V
k = Boltzmann constant in J/K
T = absolute temperature in K
e = elementary electric charge in As
I_{sc}= Short-circuit current in A
I_s = Saturation current in inverse direction in A
S = Irradiance S in W/m²